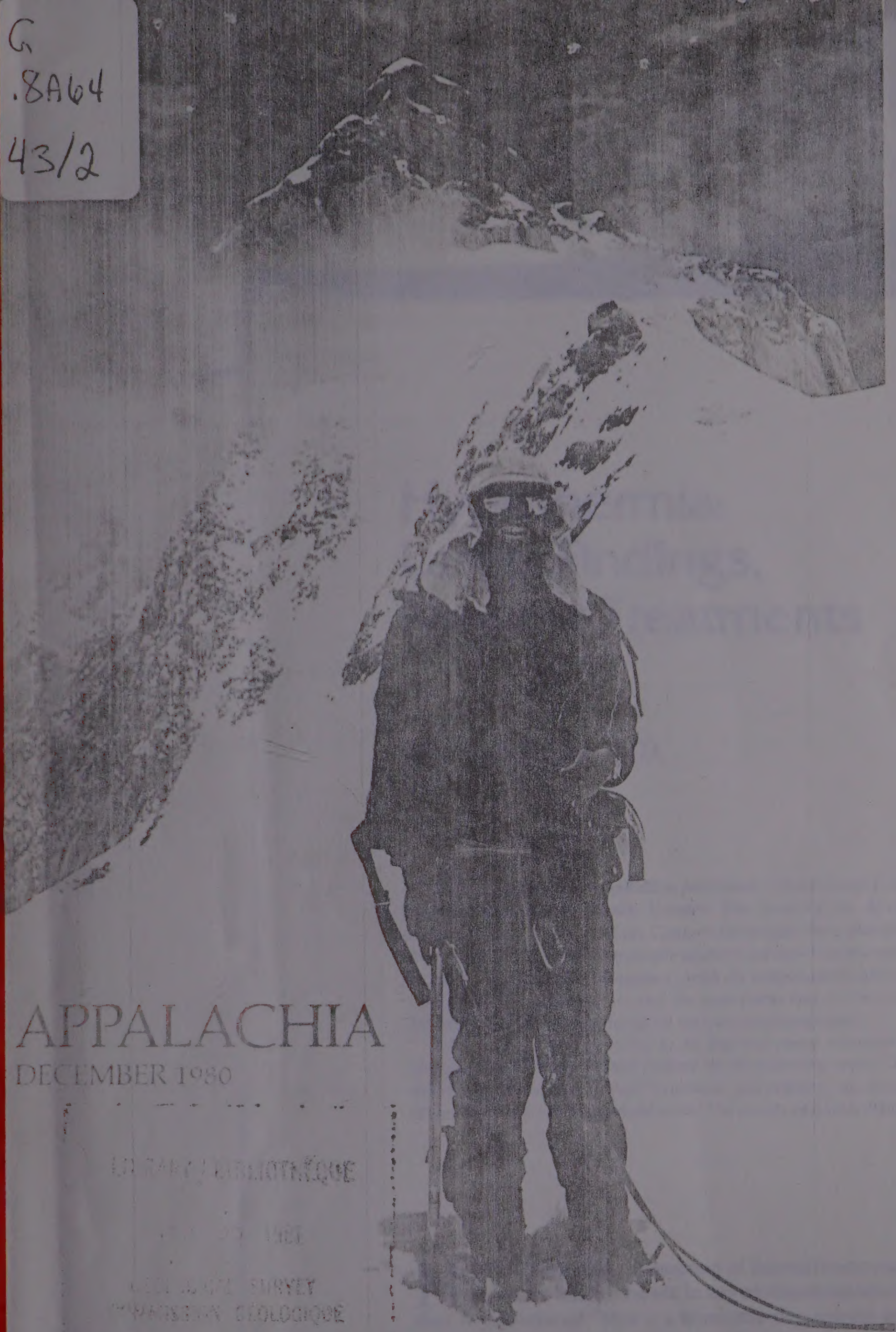

APPALACHIA

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Hypothermia: Latest Findings, Newest Treatments

Marlin Kreider, M.D.

Twenty years ago, Appalachia *published "Death from Cold,"*[1] *a pioneer article on hypothermia by Dr. Marlin Kreider. The focus of Dr. Kreider's discussion was the deaths of two young men on Cannon Mountain, New Hampshire. At the time "Death from Cold" appeared, few people understood how hypothermia could claim victims such as these in the middle of summer, with air temperatures above freezing. Since then, the concept of hypothermia — and the awareness that it is no respecter of seasons — has become part of the training of all serious outdoorspeople.*

Still, a great deal remains to be learned about resistance to hypothermia and the treatment of the hypothermic patient. In the following article, Dr. Kreider reviews recent developments in theory and treatment, particularly as discussed at the International Hypothermia Conference held at the University of Rhode Island in January, 1980.

— Editor

HYPOTHERMIA, a lowering of internal body temperatures, is a potential hazard to health and life in any environment where body heat is lost faster than it is produced. Man is a homeothermic animal; he has a sensitive control system which maintains his internal body temperature within a narrow range of fluctuation. In a man at rest at a comfortable ambient temperature, this normal range of fluctuation may be about 1.8 F/1C over a 24-hour period, but it may be much greater in an active man. If heat loss is increased and body temperature begins to drop, this control system is activated so that the body tends to "fight off" any change of temperature.

The "thermostat" of this control system is the hypothalamus, located in the base of the cerebrum. Through its control, heat production is increased by

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shivering and muscle tensing, and heat loss is lessened through constriction of peripheral blood vessels. Heat production can be increased by 5 to 6 times the resting level through shivering.[2]

FACTORS CONTRIBUTING TO GOOD RESISTANCE TO HYPOTHERMIA

Any factor which contributes to the health and fitness of the individual also contributes to the ability to produce and retain body heat during exposure to cold. Some of the most common factors are as follows:

1. A good level of fitness for endurance exercise, such as hiking, running, swimming, rowing and paddling. This type of activity should be participated in several times each week. A weekend "jock" who gets exercise only on the weekends may have little endurance and thus little resistance to cold. With an increase in fitness one can exercise longer or harder and produce more heat to maintain body temperature. Fatigue due to a lowering of fitness frequently preceeds or accompanies hypothermia.

2. Good nutritional and hydration levels. A balanced diet is always important, but is especially crucial prior to and during exposure to cold. During cold exposure, consumption of calories can contribute to a higher heat production. There have been numerous incidences cited during which hypothermia developed while food in the backpack remained untouched. This was the case in the two deaths reported in "Death from Cold." Dehydration, which can occur easily in both summer and winter, can seriously decrease an individual's heat producing ability during exposure to cold by decreasing his ability to exercise.

3. General vitality, rest and health. Any condition which may reduce the vitality of the body may decrease resistance to hypothermia. A variety of ailments ranging from temporary upper respiratory infection to systemic diseases such as diabetes, thyroid and adrenal insufficiency have been known to contribute to the occurrence of hypothermia. An example of the effects of vitality and good health can be seen in the case of Florence Chadwick, a champion English Channel swimmer. She undertook to swim the Channel one day after suffering a digestive upset. She was unable to maintain her normal number of strokes (60 per minute) and was forced to stop due to low body temperature.[3]

Occasionally a medical condition which was not previously recognized to exist will show up under the stresses of mountain hiking. It was reported in a previous issue of the journal[4] that a 19-year old woman became unconscious at a mountain hut following a long day's hike. She was later diagnosed as having a congenital potassium imbalance, about which she had been unaware. This

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1. Kreider, M. B. "Death from Cold," *Appalachia*, 130:1-13 (June 1960)..
2. Iampetro, P. F., J. A. Vaughan, P. F. Goldman, M. B. Kreider, F. Masucci and D. E. Bass. "Heat Production from Shivering," *J. Appl. Physiol.* 15:632-4 (1960).
3. Hardwick, R. G. "Two Cases of Accidental Hypothermia," *Br. Med. J.* 1:147-9 (1962).
4. A.M.C. Committee on Search and Rescue. "Unconscious Hiker in Carter Notch," *Appalachia* 170:110 (1980).

condition could easily have led to hypothermia, had it occurred in a slightly different setting.

A case history of a fatality in the mountains, reported later in this article under "Symptoms," offers further solid evidence for the importance of rest and freedom from illness.

4. Absence of alcohol, drugs and some medication. Generally speaking, alcohol, drugs, and medicine would have effects at two levels that could bring on hypothermia. First of all, alcohol and some drugs and medications could affect judgement and perception leading to wrong courses of action; secondly, they could cause both alteration of metabolism and function and a decrease of voluntary muscular activity, leading to less heat production and greater drop in body temperature. Alcohol is especially misleading in this respect. The peripheral vasodilatation that it produces warms the skin and thus produces greater comfort, but only at the expense of increased heat loss from the core of the body. This brings on the danger of hypothermia.

5. Large body size and fat content. Other factors which can contribute to increased tolerance to cold — although not normally considered to be health aids — are a large body size and fat content. Insulating fat reduces the rate of heat loss in water[5] and in air.[6] A large body size increases the time required for the temperature of the core to decrease.

6. Adaptation to Cold. Pre-exposure to cold appears to confer some benefit, although the mechanism is not clear. One aspect may be the loss of fear of the cold, making irrational behavoir less likely to occur. However, there may be circulatory and metabolic benefits — especially if there have been frequent previous exposures severe enough to produce a circulatory and metabolic stimulus. Repeated exposure to very cold water will enable competent swimmers to swim longer in cold water, but the reason for this is not clear.

THE IMPORTANCE OF PROTECTION FROM THE COLD

Without protection from the cold so that a microenvironment is created around the body, man would not survive in many places on the earth. Proper use of shelter and clothing, then, is most critical. One of the most convenient and effective principles of insulation is to trap air between several layers of clothing by means of tight bands around the openings at neck, cuff, sleeve and waist. The prevention of wetting of skin and clothing, and the subsequent cooling from evaporation, is important since wet clothing was found in most cases of death from hypothermia in the mountains (See "Death from Cold.") Wetting from perspiration and from external water are equally harmful.

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5. Keatinge, W. R. "The Effect of Subcutaneous Fat and of Previous Exposure to Cold on the Body Temperature, Peripheral Blood Flow and Metabolic Rate of Men in Cold Water," *J. Physiol.* 153:168-78 (1960).

6. Baker, P. T. and F. Daniels. "Relationship Between Skinfold Thickness and Body Cooling for Two Hours at 15 C," *J. Appl. Physiol.* 8:409-16 (1956).

7. Suess, S. E. and J. D. Isaacs. "The Breath Heater and Humidifier for Breathing Apparatus: An Initial Test and Evaluation Report." Presentation at the International Hypothermia Conference, U. Rhode Island, 1980.

Cold Water Immersion: H.E.L.P.: Protection from immersion in cold water is even more critical than protection from exposure to cold air due to the higher heat conductivity of water. Proper foam diving suits must be used for SCUBA dives, and must be tested since some suits are better than others. Recently, warming of the inspired air during the dive has contributed to thermal comfort.[7]

In unexpected immersion several factors may contribute to the reduction of the cooling rate. First, personal flotation devices (PFD) of various type may not only keep the individual afloat,[8] but may give some thermal protection. Included in this category could be antiexposure suits of various kinds. Using the same principle, in the absence of any protective devices, one can trap air in the clothing and boots by closing them tightly and can prevent it from escaping by avoiding struggling movements. It is generally agreed that swimming and struggling movements greatly accelerate the loss of heat. One should remain quiet and not attempt to swim unless he is very close to a boat or shore. One should definitely not take off his clothing when abandoning ship. In fact, he should put on as much warm clothing as possible including shoes and boots, and hat.[9].

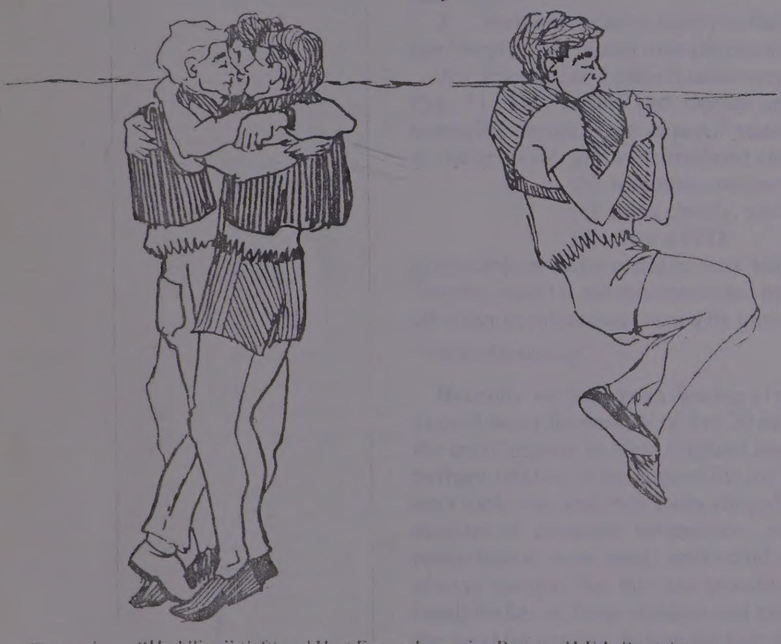

Figure 1 "Huddling" (left) and Heat Escape Lessening Posture (H.E.L.P.) (right)

8. Kreider, M. B. "Death and Survival During Water Immersion: Account of a USAF Plane Crash off of Cape Cod, July 1965." *Aerospace Med.* 38:1060-62 (1966).
9. Goethe, H. Paper presented at the International Hypothermia Conference. U. Rhode Island, 1980.

During water immersion a special modified fetal position is recommended. This is known as the Heat Escape Lessening Posture, or H.E.L.P. (Fig. 1) Characteristics of this position include:

1. Drawing the knees together, but keeping them below the trunk for stability.
2. Holding the arms tightly to the sides of the ribs with the elbows bent and the lower arms crossed over the chest, or
3. Facing 2 or 3 other floaters very closely in a tight circle (huddle position, Fig. 1). This covers and shields areas of the body where rapid heat loss normally occurs. One expert[10] stated that proper action following boating accidents is to: (a) wear insulated clothing
(b) minimize movement
(c) think clearly, and
(d) wear a PFD.

Being able to swim could be very helpful. "Drown proofing" (lowering head into the water) is not recommended by this authority. He also stated that almost all water accidents are caused by gross carelessness or ignorance.

"Near-drowning":

Recently we have been hearing of recovery following complete submersion in cold water for periods of 5 to 30 minutes, called "near-drowning." Most of the early reports in New England involved children who fell through ice and perhaps held on to the edge of the ice for 10 minutes, whereupon unconsciousness took over and their faces slipped into the water. If rescue came before 30 minutes of complete submersion, and if the proper aggressive methods of resuscitation were used, uneventful recovery occurred in some cases. I had always thought that this was possible because temperature fell rapidly in the small bodies of these children and greatly decreased the metabolism, and thus the need for oxygen, before the face was submerged. But now there are reports of adult survival from more than 15 minutes of total submersion in situations where no precooling could occur. Two examples of this have been reported in the last two years: An 18-year old woman was revived after about 15 minutes of total submersion in the Acushnet River at New Bedford, Massachusetts earlier this year, [11] and a 24-year old woman was revived after submersion for about 25 minutes in the Charles River in Boston. [12] Internal temperatures had dropped to 82F/28 C and 84F/29 C, respectively.

Dr. Martin Nemiroff from the University of Michigan Hospital at Ann Arbor has treated an impressive list of submerged hypothermic patients. One submersion of an 18-year old man who survived uneventfully lasted for 38 minutes. [13]

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10. Smith, D. S. Paper presented at the International Hypothermia Conference. U. Rhode Island, 1980.
11. "Woman with No Heartbeat Thawed Out, Saved After River Plunge," *Boston Sunday Globe*, Jan. 27, 1980.
12. Cooke, R. "The Water Was So Cold It Helped Save Her Life," *Boston Sunday Globe*, Mar. 25, 1979.
13. Nemiroff, M. J., G. R. Saltz and J. C. Weg. "Survival After Cold-Water Near-Drowning: the Protective Effect of the Diving Reflex," *Amer. Rev. Resp. Dis.* 115(4, Pt. 2):145(1977).

Mammalian "diving reflex":

Dr. Nemiroff suggests that the mammalian "diving reflex" found in diving mammals may be in operation in these human patients and may have helped in their survival. The main features of this reflex in these mammals include:

1. A slow heart rate (bradycardia) during submersion of the head, and
2. A constriction of all the peripheral and non-critical blood vessels. These two responses in the diving mammal result in a major reduction in blood flow through the outer tissues and a conservation of the blood for the major organs of the core such as the heart, lungs and brain.

However attractive as this comparison of the hypothermic patient's response with the mammalian "diving reflex" may be, there exist certain major differences. First, while bradycardia is also found in man as well as in these animals during face and body submersion in mild water, in cold water one might expect the reverse — an increase of heart rate. In addition, while the peripheral vasoconstriction produced by water submersion in animals is also found in man when he is in the cold, it would hardly contribute to the rapid heat loss which seems to be necessary for reduction of oxygen needs and survival. There is some question, however, about the extent of vasoconstriction that would occur during the resulting violent shivering in man. Shivering is not a part of the diving reflex. At the present time the mechanism of survival in these cases may not be fully understood. But it is important that in a supposed drowning in cold water, resuscitation and rewarming be initiated and continued until the individual is warm, either dead or alive. In fact, it is now the law in Sweden that no hypothermic victim may be declared dead until he is first rewarmed.

INCIDENCE AND CAUSES OF HYPOTHERMIA

Hypothermia occurs not only in cold climates but also in warmer parts of the globe, such as Texas, Israel, Jamaica and other places where the ambient temperature never drops below 16 C. The contributing causes of hypothermia continue to be much the same as before:

1. Exhaustion and exposure during mountaineering or hunting trips.
2. Immersion and submersion in water. Boating accidents (especially among drinking fisherman), capsizing of gale-tossed small pleasure or fishing boats, shipwreck, and occasional downing of aircraft are some of the major causes of accidental immersion hypothermia.
3. Another cause of hypothermia is alcohol, drugs or poison consumption. Many cases of hypothermia are reported which seem to be caused by the combined depressing effects of alcohol, drugs, and poisons. Implicated in this group are barbituates, amphetamines, carbon monoxide and various other toxic substances. Hypothermia was also found after treatment of alpha methyl dopa for relief of hypertension, and after administration of chlorpromazine and a combination of lithium carbonate and diazapam for the control of aggressive behavior.

Survival from some of the lowest body temperatures has occurred after the consumption of some of these substances. This has led me to theorize[14] that recovery was due to undepleted energy stores in the tissues that are now available for rewarming and recovery. This energy was prevented from being depleted during cooling by the inhibiting effect of these substances on shivering and metabolism in general. Of at least 35 cases of survival from core temperatures of 77F/25C or lower (death generally occurred between 79F/26C and 82.5F/28C), all individuals were under the influence of alcohol, drugs, or poison, or they were either very young or very old, or they were under the influence of a medical condition such as diabetes coma. A common effect of all these conditions was a decreased metabolic response to the cold. This should mean that there was more energy available for rewarming, but it would also mean that body temperature would have dropped more rapidly during exposure to the cold.

Some questions have been raised about other beneficial effects of alcohol. In small laboratory animals it has been reported that alcohol did reduce the incidence of ventricular fibrillations, cardiac arrest, the mean lethal temperature, and the temperature of restarting the heart in hypothermic animals.[14]

4. Infancy and old age. In both extremes of age, temperature regulating ability may be poorer. It is not certain that all old people suffer from poor temperature regulation. Numerous reports from English and American origin reveal that many older people, living alone and in poorly heated rooms, perhaps with inadequate clothing, suffer from hypothermia. However, this does not mean that recovery from hypothermia is poor.

5. Medical conditions. Many cases of hypothermia are complicated by medical conditions and disease. In most cases the disease contributed to the development of hypothermia and, at the same time, complicated the recovery from hypothermia. Some of the diseases are diabetes, myxedema, myocardial infarction, central glucopenia, and cerebral vascular accident. Also, damage or patholgy of the central nervous system appears to be implicated. An unusual defect has been reported which allows hypothermia to develop for several hours and then spontaneously disappear. This process may be repeated several times in a day and is called "episodic hypothermia."[15]

SYMPTOMS

Since the publication of "Death from Cold," in which the physical symptoms of deterioration at different core temperatures were graphically represented, these symptoms have been published many times. Some of the most common symptoms include:

1. violent shivering followed by cessation of shivering
2. fatigue and weakness generally associated with exercise

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14. Kreider, M. B. "Diseases Due to Extreme Cold Stress," In *Progress in Biometeorology*. S. W. Tromp, Ed. Amsterdam: Swets and Zeitlinger, 1977. Vol. I Part II: 113-26.
15. Thomas, D. J. "Episodic Hypothermia," *Lancet* 2:449 (1973).

3. poor coordination causing stumbling and other clumsy acts
4. poor speech articulation
5. poor judgement and hallucinations
6. feeling of deep body cooling and numbness accompanied by very cold chest and abdominal pain
7. diminished respiratory rate and pulse
8. unconsciousness followed by death.

There does not appear to be one special symptom that distinguishes mild from severe hypothermia. There is a great variability from person to person in the body temperature at which various symptoms appear. But certainly unconsciousness or semiconsciousness and the inability to walk might suggest severe hypothermia. It may be interesting to see the symptoms as they developed in a mountaineer and a channel swimmer.

An experienced mountaineer had agreed to lead a group into the mountains. However, he had been out every night during the previous week and was very tired. He regretted having obligated himself to lead the climb. He also was not feeling well, and friends who had seen him during the week agreed that he did not look well. As the party climbed the temperature dropped and the wind came up. Toward the summit, they were in a white-out condition. The leader had stopped to put on more clothing, and after deciding to begin the descent because of the weather it was discovered that two people were missing. After a 45 minute search in the direction of the summit, they had not been found. The leader was extremely depressed and very apprehensive, as he recognized the potential danger of freezing that the missing men were facing. Everyone was wet and cold and the leader's pupils were dilated. After 3 hours of descending the leader missed a wand, but when it was called to his attention he insisted that he had not missed one. This was soon followed by some faltering. He insisted that every thing was alright, even though he appeared to be confused and desired to take the arm of another climber. He developed difficulty in placing his right cramponed foot in the glacier ice. About half an hour after he missed the wand, the leader fell to his knees. From then on he was incoherent. The group decided to seek shelter on the mountain and, after another hour, found a small crevasse. The leader and other wet climbers were carried here where they huddled together. The breathing of the leader became heavy and labored, and he died within the next 1½ hours.[16]

Florence Chadwick became hypothermic during her first attempt to swim the Irish Sea. After more than 11 hours of swimming she resisted an attempt by friends to remove her from the water, but after they finally succeeded in bringing her aboard she collapsed unconscious. Her pulse and blood pressure could not be detected and heart sounds were slow and faint. Respiration was slow; her body was cold as in death and there was doubt about her survival. No internal temperature was recorded. However, after 48 hours she was fully recovered.

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16. Hunter, W. C. "Accidental Hypothermia," *NW Med*. 67:735-9 (1968)

RESUSCITATION — PHYSIOLOGICAL PRINCIPALS

Since the 1940's, when interest in hypothermia began to grow, it has been believed that the rate of body cooling and the length of time that the body was cooled should determine the rate and method of rewarming. The then meager knowledge of hypothermia was presented in 1955 in *Man in a Cold Environment* by Burton and Edholm.[17] Some major functional differences between rapid and slow cooling reported at this early date have now been confirmed. For one, hypoglycemia may develop during rapid cooling to levels two or three times the normal and may be due to an upset in insulin and adrenocortical control. If cooling is slow and prolonged, hypoglycemia develops as the glucose and glycogen stores of the body are depleted. Generally, in hypothermia, the blood sugar level can be quite erratic. Also, when cooling is slow, progressive dehydration develops due to plasma loss to the tissues and increased urine production. It is most important that fluids be replaced as part of the early treatment, especially after slow cooling over a long time.

Several terms have been applied to identify the type of cooling such as "acute," "subacute," and "chronic." "Acute" was first applied to hypothermia in which cooling took place rapidly (as in cold water immersion) and generally occurred in less than 12 hours and sometimes for days. "Subacute" would be cooling conditions between acute and chronic.

"Afterdrop":

Another physiological principle important to recovery is "afterdrop." Core temperature continues to drop after rewarming has begun, and may fall enough to produce fatal cooling of the heart. This process is initiated by the application of heat to the skin (Fig. 2). The heat in turn stimulates a reflex vasodilatation of the cold-constricted blood vessels of the skin. As blood begins to pass through the skin and subcutaneous tissues it is cooled to temperatures below the tolerable limits for the heart, so that, as it returns to the heart, cardiac irregularity or cessation develops. It is important, then, to prevent the use of moderate rates of rewarming such as those afforded by hot water bottles, heated blankets, etc. These initiate the vasodilatation of the skin but do not add much heat. If surface rewarming is used it must provide massive amounts of heat in as short a period of time as possible to shorten the period of time of the "afterdrop" and reduce its magnitude. Immersion of the trunk in a tub of warm water at 105-110F/41-44 C. is one way to accomplish this. Another ideal method is to rapidly rewarm the core first, and then allow the heat to spread to the periphery through normal circulation. There are now sophisticated methods available for core rewarming in a clinical setting. Still another method that may reduce or eliminate "af-

17. Burton, A. C. and O. G. Edholm. *Man in a Cold Environment*. London: Edward Arnold Ltd., 1955.

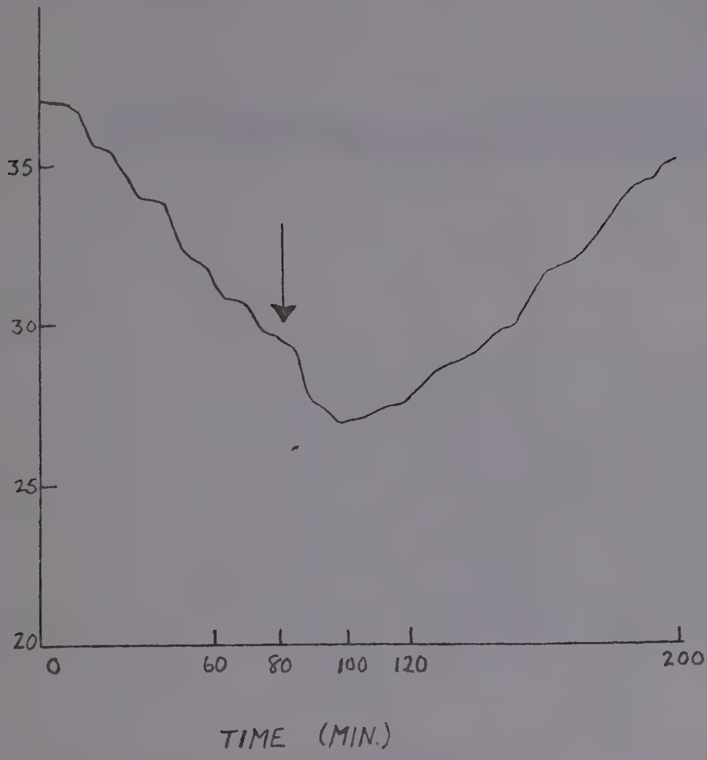

Figure 2 The "afterdrop" of rectal temperature (in centigrade degrees on vertical axis) that occurs in man after surface rewarming has started (at arrow).

terdrop" is very slow rewarming from within due to metabolic heat. This takes a long time (possibly many hours) because metabolism is depressed by the cold, but it does prevent massive return of cold blood to the heart. However, most experts agree that the best rewarming method available to prevent the danger of "afterdrop" following acute hypothermia is rapid core or rapid surface rewarming.

Rapid core rewarming may be needed after any type of cooling where there has been cardiopulmonary arrest, since defibrillation is ineffective at core temperatures below 82.5-86F./28-30 C.[18, 19]

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18. Editorial "Treating Accidental Hypothermia," *Br. Med. J.* 6149:1383 (1978).
19. Ledingham, I. McA. and J. G. Mone. "Accidental Hypothermia." *Lancet* Feb. 18, p. 391 (1978).

There is less agreement on the proper rewarming method in cases of "chronic" hypothermia. Some of the earlier experts thought that the rapid procedures produced uneven rewarming of tissues and organs, resulting in metabolic imbalances. Another perceived problem was a "rewarming collapse" which involved rapid dilatation of the vascular system at a time when blood volume was considerably diminished, producing very inadequate blood pressures and circulatory collapse. Slow rewarming would allow for a gradual readjustment of these functions and could prevent a further crisis. Numerous people still recommend slow rewarming for profoundly cold individuals. However, others disregard these problems and advocate rapid rewarming for all conditions of hypothermia. They claim that by using blood volume expanders such as lactated Ringer's solution, given I.V., circulatory collapse may be prevented.

RATE OF BODY COOLING

It has been pointed out earlier that the rate of body cooling may influence the rate and method that should be selected for rewarming. The rate of cooling is extremely variable from one individual to another and from one set of environmental and insulative conditions to another. This difference is sometimes due to variations of those factors of health and fitness listed earlier. Also, there seems to be an infinite number of combinations of environmental conditions such as temperature of air or water, wind, humidity, and radiation, all of which are greatly altered by varying amounts of insulation.

The amount of protection offered by insulation depends upon the wetness of the material. But even in water immersion, where the contact with the cold is more uniform, there is great variability in the cooling rates. Average survival times were determined from reports of accidents at sea in 1946 [20] and these values have been quoted many times since. From these reports it was concluded that survival cannot be expected if exposure is more than:

30 minutes at 32 F/O C.
60 minutes at 40 F/4.5 C.
3.5 hours at 50 F/10 C.
6 hours at 60 F/16 C.

Inspite of these maximal values we know that channel swimmers can stay in water at 60 F/16 C. for 12 to 20 hours, and that three men survived a U.S. Air Force plane crash in the Atlantic Ocean off Cape Cod and were rescued after floating for 103 hours in 52 F/11 C. water (Fig. 3). Of the 12 men who came down, the men who survived may have had the largest amount of body fat and they also had antiexposure suits; however, the suits were considerably torn so that the amount of protection is not known. [8]

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20. Molnar, G. W. "Survival of Hypothermia by Men Immersed in the Ocean," *J.A.M.A.* 131:1046-50 (1946).

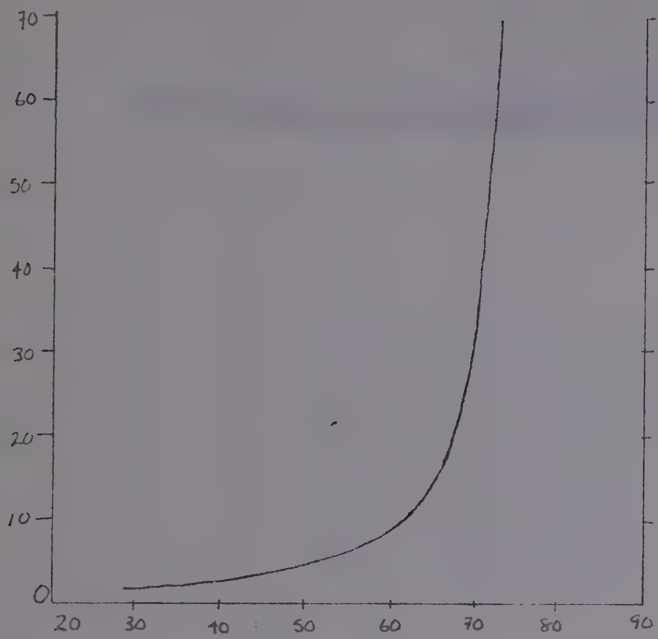

Figure 3 From study of survival from shipwreck in 1946,[20] survival would be expected only under conditions to the right of the curve. The vertical units are in hours; the horizontal axis is water temperature in degrees Fahrenheit.

The actual rates of temperature drop that have been reported for immersion in water vary from 2.3 F/1.3 C. per hour for two men in 43 F/6.1 C. water[21] and 5.4 F/3.0 C. per hour for 5 men in 50 F/10 C. water,[22] to 21.5 F/12 C. per hour (11 F./6 C. per 30 minutes) in a 4-year old child who was found face down in icewater after one-half hour of immersion.[23]

But if the newspaper accounts of hypothermic near-drowning of the two women reported earlier are accurate, their cooling rates were unbelievably higher than anything previously reported: 68 F/38 C. per hour (17 F/9.5 in 15 minutes of water exposure) and 36 F/20 C. per hour (15 F/8.4 in 25 minutes).

21. Behnke, A. R. and C. P. Yaglou. "Physiological Response of Men to Chilling in Ice Water and to Slow and Fast Rewarming," *J. Appl. Physiol.* 3:591 (1950).

22. Spealman, C. R. "Body Cooling of Rats, Rabbits and Dogs Following Immersion in Water: With Few Observations on Man," *Am. J. Physiol.* 146:262 (1946).

23. Russell, E. S. "Unintentional Hypothermia," *Canad. Med. Assoc. J.* 85:846 (1961).

There is some reason to believe that body temperature drops more rapidly once it has fallen to a certain level even though the exposure conditions remain the same. This may not be true for very rapid heat loss, but during those exposure conditions where the body temperature is dropping to a dangerously low level over a period of several hours. In the accompanying figure this phenomenon has been demonstrated, based on observatory of a laboratory rat. During a period of continuous cold exposure of the same intensity, the core temperature dropped steadily until it reached a level beyond which it suddenly dropped more rapidly, accompanied by a drop in metabolism and heat production (Fig. 4). This same phenomenon has been demonstrated in larger animals.

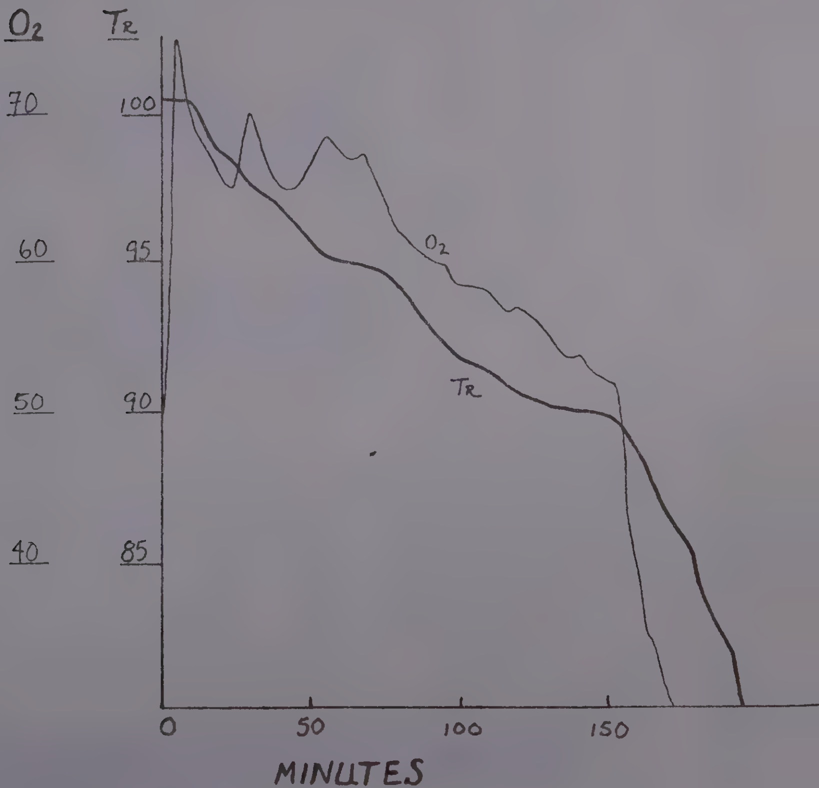

Figure 4 Notice the sudden simultaneous decrease of oxygen consumption (O_2) and rectal temperature (T_r) curves in the cooling rate. Oxygen consumption is in units of ml/kg/min. and T_r in Fahrenheit degrees.

such as the dog, and occurs at core temperatures from 92 to 95 F./33.5 to 35.5 C. [22] In some severe cooling of man it has also been demonstrated to occur at about 91.5 to 93 F./33 to 34 C. [22,24] but more data is needed before we can be certain of the characteristics of the temperature to drop even faster. This means that the temperature drop during exposure must be stopped as soon as possible, because endogenous rewarming becomes less possible thereafter and death will follow quickly.

RESUSCITATION TECHNIQUES

Hypothermia demands attention. It is a medical emergency. It generally does not go away by itself unless the victim is removed to a warmer environment. The goal is to get the victim warm again. Rewarming must occur either from internal metabolic heat after heat loss is first reduced by insulation or warmer environments, or by the application of external body heat. In addition, rewarming must be accompanied by appropriate supportive treatment during its various stages. The timing of this treatment requires continuous observation and much wisdom. There is probably no simple treatment or management of hypothermia which is appropriate for all cases; each case must be treated according to its own requirements.

Ever since the beginning of our awareness of hypothermia there has been much controversy and uncertainty concerning the methods of rewarming and supportive treatment, and this uncertainty still exists. The treatment that can be given in the field or site of the accidental hypothermia is different and more simple than that available in a clinical setting.

In the Field

We are speaking here of an outdoor location separated by more than an hour's travel from a shelter containing heat and water, where the victim could remain for hours or days if necessary without further exposure to cold. For some of the methods of treatment, any facility short of hospital facilities might be considered field conditions.

Mild Hypothermia (Probably Above 90 F/32 C).

When symptoms of even mild hypothermia first appear, it is time to act. Generally, action must be taken by others (an observant leader or companion) because of the dulling of comprehension of the victim and his inability to act. Recognition of the condition is frequently hidden by the symptoms of fatigue and exhaustion generally accompanying hypothermia.

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24. Alexander, L. "The Treatment of Shock from Prolonged Exposure to Cold, Especially in Water." Rept. 250 U. S. Dept. of Commerce (Dachau Exeriments) (1945)

The following points of treatment should be considered in the treating of mild hypothermia in the field:

1. The total exposure to cold must be reduced. If this exposure continues at an unreduced level, that latter part of the body temperature curve may rapidly be reached where there is a precipitous drop of temperature (see "Rate of Body Cooling" above). In water or wet clothing this can happen very rapidly. Only one and a half hours elapsed between the first signs of hypothermia and death in three cave explorers.[25] I may have been the first to report (in "Death from Cold") that wet clothing almost always accompanies death from hypothermia. High winds, especially the record-breaking gusts of the Presidential Range, remove heat rapidly from the body. Thus it is essential to remove the victim from the wind and to replace wet clothing with dry. If one is close to the treeline it may be worth the time to come down to it before stopping. If dry clothing is not available, a vapor barrier such as a plastic film, even a garbage bag, wrapped around wet clothing will reduce the evaporative heat loss and keep rain and ground moisture out. This may be more desirable than changing the clothing in an unprotected area. A sleeping bag or other insulation under the reclining victim is most important — especially around the head and neck.

2. Heat should be supplied from any available sources such as a camp fire, stove, hot water canteen, heated rocks, and warm human bodies. Any source of heat is welcome under these conditions.

3. Food and water, preferably hot, should be consumed.

4. Rest, if exhaustion is present: if the victim is not exhausted and mild hypothermia is just beginning, exercise, such as rapid walking with dry clothing tightly closed to trap warm air, is a most effective way of rewarming. (In deeper hypothermia this would be dangerous.) However, it may be necessary to rest for a long period of time and even camp overnight. If help is needed, someone should remain with the victim while others go for help. Information about the condition, location, and time of the recognition of the hypothermia, should be written down before a messenger leaves the scene for help. Excited and or exhausted messengers carrying verbal information can misinform and confuse rescuers.

Severe hypothermia (Probably below 90 F/32 C).

In this condition the subject is probably reclining, semiconscious, out of contact with reality, and not responsive or responsible. In some severe cases he may appear to be dead. All the vital signs may be absent. Respiration and heart rate may not be detectable and even the pupillary reflex may be absent. It is

25. Kreider, M. B. "Physical and Physiological Factors in Fatal Exposures to Cold," *Natl. Speleol. Soc. Bull.* 29:1-11 (1967).

believed now that in the past, many victims exhibiting these symptoms have been treated as dead, although they could have been revived. Obviously, this is a serious emergency and death will certainly follow without rather unusual treatment.

The following points of treatment should be considered in the handling of severe hypothermia in the field:

1. An examination should be made and treatment given for serious injury and for anything blocking the upper respiratory system, especially if respiration appears to be absent.

2. Cardiopulmonary resuscitation (CPR).

The administration of CPR to a severely hypothermic victim was one of the most hotly debated issues at the recent International Hypothermia Conference, and, in spite of the desire of some to get the issue settled so that a doctrine could be established for use by emergency medical technicians, it was concluded that more research was first necessary. If breathing and heart rate are very depressed and if it is not clear whether ventricular fibrillation (V.F.) is occurring or not, it is the natural inclination to assist these processes by CPR. A portable ECG monitor might be of some help but is very expensive. Few rescue teams would be expected to have one.[26] These measures could be lifesaving under normothermic conditions and even under some hypothermic conditions.

But the big objection comes from the possible harm that may be done by CPR if the heart is not in ventricular fibrillation (VF). Since the cold heart becomes hypersensitive and irritable, any small mechanical manipulation can cause VF. This uncoordinated beating of the heart muscles can soon cause death due to failure of the pumping action of the heart. Once V.F. has begun, it may not be stopped until death or rewarming have occurred. So, once it is started in the field, CPR — or especially external cardiac massage — may have to be continued until the victim has arrived at a medical facility. Sometimes it is very difficult and exhausting to administer CPR during transport, especially while the victim is being carried down a mountain trail.

It should be borne in mind, however, that hypothermic subjects have been resuscitated after 30-45 minutes of asystole, especially after having cooled rapidly in cold water.[27] One indication for the use of CPR, agreed upon by many at the Hypothermia Conference, is a sudden change for the worse in cardiovascular function. It would seem to follow, because of all certainty, that *when in doubt CPR should not be used on a hypothermia victim in the field*, except, possibly, for immersion victims.

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26. "Treating Accidental Hypothermia," *Lancet* 1:701-2 Apr. 1 (1978).

27. Bangs, C. P. Paper presented at the International Hypothermia Conference, U. Rhode Island, 1980.

3. Reduction of Heat Loss and Rewarming. Heat loss must be reduced by the same methods as for mild hypothermia, which has already been described.

Rewarming from severe hypothermia, a major goal of treatment, may not be possible in the field. Facilities for rewarming are generally not available unless one is close to an adequate mountain shelter or is picked up by a sizeable boat. However, a limited amount of heat should be supplied to the clothing and insulation, if available, *as a deterrent against further heat loss — not in an attempt to rewarm the victim.* This heat could be in the form of warm canteens, warm rocks, portable heated blankets (heated Sarong) or inhalation of moist heated air or oxygen. But the seriously hypothermic victim should not be given any warm drinks or, for that matter, anything by mouth. It would then be important to get the victim to a medical and rewarming facility as fast as possible.

One special caution should be kept in mind. Just as external cardiac massage may initiate V. F., so may any kind of mechanical movement of the body, including holding it in a sitting position and twisting and bending it to remove wet or frozen clothing. In addition, it is believed that nasopharyngeal intubation, as well as sudden decreases in the carbon dioxide concentration of the blood which might occur in sudden massive respiratory support, may also initiate V. F.[28] So, *handle the victim very gently.*

4. Medication and Other Treatments.

One treatment that could be helpful in the field is warm Ringer's solution given I. V.[29] This may be difficult to accomplish in a cold environment: it may not be easily available and it may be hard to keep warm But one way is to carry it under the clothing of a rescuer. This treatment would serve two purposes; it would increase blood volume thus helping to prevent circulatory collapse and it would help to rewarm the core. There is little evidence that drugs given at this time would be of value, due to the depressing effect of the cold. But what the appropriate treatment may be under these conditions is unclear in the minds of many. One will want to do something, but what?

In the Medical Facility:

If the seriously hypothermic victim can be brought from the field to a medical facility, sophisticated rewarming and supportive treatment can be applied which is not available and cannot be used in the field. The most common points of treatment include the following:

1. Respiratory support.

If pulmonary resuscitation has been initiated in the field, it should be continued. Positive pressure breathing machines supplying oxygen through

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28. Keatinge, W. Paper presented at the International Hypothermia Conference. U. Rhode Island, 1980.

29. Hamlet, M. P. Discussion. International Hypothermia Conference. U. Rhode Island, 1980.

mask or endotracheal tube (tube in the airway) may be helpful. But this may cause dangerous ventricular fibrillations. One hundred percent oxygen may be used for several hours, and 50 percent for longer periods.

2. Cardiac support.

If cardiac support has been started in the field it probably must be continued because of the resulting ventricular fibrillations. If it has not been started it may have to be, if ventricular tachycardia, fibrillations or arrest occur. The most common support is in the form of closed-chest cardiac compression which may have to be continued until rewarming to about 82.5 to 86 F/28 to 30 C has occurred. This could require several hours of time. At this heart temperature and above, electrical defibrillation is effective. Medication may be also desirable. Choices included lidocaine (15 mg/kg), generally used for arrhythmias, or digitoxin or digoxin, generally used for congestion.[30] However, a warning has been recently sounded regarding lidocaine and propranolol, which appear to have little effect in the hypothermic dog heart. Dopamine, however, alone or in combination with lidocaine, reverses the cardiovascular depression of hypothermia.[31]

3. Rewarming.

A method must be selected and begun so that rewarming may occur as soon as possible. While the method to use may be controversial, some guidelines may be found under "Methods of Rewarming" below.

4. Administration of Fluids Intravenously (I. V.) to Increase Plasma Volume.

Hypothermic victims are almost always dehydrated. This may be due to: (a) increased diuresis; (b) loss of fluid from plasma to tissue; (c) inadequate fluid intake.[27] The amount of fluid given in the medical facility will be influenced by how much has already been given in the field, and by current urinary output. One suggestion is to administer about 300 ml. of saline solution immediately after the victim is found and up to 1000 ml in the first hour. Glucose (5%) may be administered; however, in acute hypothermia, hypoglycemia may already be present.

5. Monitoring of Temperature, Heart, Vital Signs and Various Blood Components.

In order to determine the extent of supportive treatment needed during the rewarming the following parameters should be tested repeatedly from venous blood — CBC, BUN, creatinine, electrolytes, glucose, amylase, calcium, fibrinogen, prothrombin time and platelet count. Arterial gases and pH should be monitored as frequently as necessary and as often as every 15 minutes, and

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30. Miller, J. Paper presented at the International Hypothermia Conference. U. Rhode Island, 1980.
31. Nicodemus, H. et. al. Presented at the International Hypothermia Conference. U. Rhode Island, 1980.

pH must be adjusted for temperature. Temperature measurements can indicate whether rewarming is too fast or too slow and may help in the timing of various procedures.

6 Administration of Bicarbonate, Adrenocortical or Adrenomedullary Hormones and Heparin.

Acidosis is generally found in hypothermia, so administration of bicarbonates is helpful. But sometimes the reverse, an alkalosis, is found. This may or may not be related to other diseases.[30]

The indications for the use of corticosteroids, epinephrine or thyroxin are not as definite and there are physicians who are either strongly for or against their use. One warning must be kept in mind concerning the use of drugs in the hypothermic subject. *Most drugs have little effect on the metabolically depressed cold body, but their effects will be exerted mainly when the tissues warm. This can greatly complicate the clinical picture.*

Not all of these supportive treatments need to be given in every case, and perhaps each treatment should be administered only if it is clear that it is needed.

METHODS OF REWARMING

Simple methods of rewarming which can be done in the field should be tried only on cases of mild to moderate hypothermia. If used on severe hypothermia they should be used only to prevent further heat loss but not to rewarm. Most of the recommended methods for rewarming from severe hypothermia require sophisticated techniques and equipment available only in a medical facility.

Rewarming methods can be classified as: (1) external or surface rewarming, or (2) internal or core rewarming. The surface rewarming methods for use in rewarming from severe hypothermia are possibly the easiest but most dangerous of all the rewarming methods for the victim. Surface rewarming methods include:

I. Total immersion of the trunk or of the trunk and limbs in warm water
II. Heated blankets or suits (sarong)
III. Hot objects such as water bottles, rocks, human bodies, etc.

I. Immersion in water:

This is the time-honored method recommended for chronic hypothermia. The water in the tub must be held at 105 to 110 F. 41 to 43.5 C. This requires continuous rewarming or replacement of the water which is rapidly cooling due to heat lost to the cold body and the atmosphere. Of course, care must be taken not to burn or drown a comatose victim. Supportive treatment such as external cardiac massage may be somewhat difficult to administer in this position. In recent years it has been suggested that the limbs be kept out of the warm water and possibly bandaged at their proximal end to reduce venous return and that they should not be rewarmed until the trunk has been rewarmed at least partially and the metabolism and vital signs have stabilized.

II. Heated Blanket or Suit (Sarong):

This method cannot rewarm the body as rapidly as water immersion because of less surface contact. Included in this method are electric blankets, hypothermia blankets used to produce profound hypothermia for surgery, etc. This method would probably fall under a moderate or intermediate rate of warming, and thus would not meet the need for fast rewarming of a deeply hypothermic victim. It could, however, be used for a mildly hypothermic victim or to prevent further heat loss in any victim in a very cold environment. Portable units have been made for the military and the AMC possesses several of them.[32] A 10-lb. power source including a cylinder of proplyene is attached to an 8-lb. plumbed nylon liner filled with glycol-water solution. This liner should be placed around the victim and inside a sleeping bag or other external insulation. It is designed to function at -50 F/-30 C and to run for 15 to 20 hours. It was tested at Pinkham Notch at 5 F/-15 C and warmed to 95 F/35.5 C in 30 minutes.

III. Hot Objects: Rocks, Water Bottles or Human Bodies:

This method of rewarming may be in a similar category to the previous one of heated blanket or suit. The heat provided may be even less than by the heated blanket because of the limitation on the small amount of surface contact with the body. It would have the same limited usefulness — the rewarming of mild cases and prevention of further heat loss from any hypothermic victim.

The greatest progress has been made recently in the methods of rewarming of the internal or core areas. In this category are included:

1. peritoneal dialysis
2. partial or complete cariopulmonary bypass
3. hemodialysis
4. thoracotomy and lavage of the heart area (mediastinal irrigation)
5. warm moist inspired air or oxygen
6. intragastric balloons
7. gastric and colonic lavage
8. spontaneous rewarming.

Peritoneal dialysis:

This may be one of the best methods.[33] In this procedure one (or two for speed) puncture hole is made through the abdominal wall into the cavity and a catheter inserted. A potassium-free stock dialysate or Ringer's lactate or 5 percent dextrose in water at about 104 to 109.5 F/40 to 43 C is rapidly pumped or allowed to flow from a bottle into the peritoneal cavity and is immediately withdrawn. This may require 20 minutes. Only 6 to 8 exchanges may be

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32. Wendelowski, K. "Hypothermia Treatment Units," *Appalachia* 44:112 (1977).

33. Rueler, J. B. and R. A. Parker. "Peritoneal Dialysis in the Management of Hyperthermia," *J.A.M.A.* 240:2289-90 (1978).

necessary. It is recommended that monitoring of fluid electrolyte and acid-base status be made during dialysis. However, as simple as the method may seem in the hands of the experts, two physicians claim that it frequently is not complication-free.[34]

Partial Cardiopulmonary Bypass and Hemodialysis:

In both of these methods a stream of blood is directed from the body through a heat exchanger, and either through the artificial lung or through the artificial kidney. Through these methods, heat can be added to the core very rapidly and exchange of oxygen and carbon dioxide can be speeded up, or, in the case of the artificial kidney, complicating drugs and other harmful substances can be removed. Thus support can be given to a failing circulation as well as supplying heat. These methods require a groin incision under local anesthesia and insertion of a catheter or needle into the femoral artery and iliac vein. A team of professionals is needed to operate the artificial lung or kidney, and may be available only in larger medical centers. The partial cardiopulmonary bypass has been used on numerous cases of hypothermia and is highly recommended.

Thoracotomy and Lavage of Heart Area (Mediastinal Irrigation):

This method is a rather radical procedure because it requires cutting through the thoracic wall and supporting respiration by use of a positive pressure pump through a tracheotomy. Warm fluids are directed over the heart and internal cardiac massage is applied. The defibrillator may be used to alter the cardiac arrest or ventricular fibrillation.

Warm Moist Inspired Air and Oxygen:

This method was introduced in 1972[35] and involves the production of the initial heat by a burst of CO_2 from a cylinder passed over soda lime. Thereafter, heat is maintained by the CO_2 in the steady flow of expired air. The system also supplies a high O_2 mixture and a humidifier. Other methods using propane or electric steam heat are available from Scitech Products, Victoria, B. C.

Considerable debate has gone on in the scientific literature as well as at the International Hypothermia Conference on the merit of this method of rewarming. In the normal process of breathing without any assistance, air is taken in, warmed to body temperature, and saturated with moisture in the upper respiratory tract. Thus, in both warming and humidifying of the air, heat is lost from the body. But in supplying warm moist respiratory air, heat loss is reduced and heat may even be added to the body. There are some advantages to this method. First, it is easy to administer, especially in a medical facility, and field methods are currently being developed. Second, it reduces dehydration. Third, it prevents hardening of mucus in the lungs. Fourth, it seems to prevent the "afterdrop" that accompanies rewarming methods. The disadvantages include, first, the risk of face or mouth burns, which can be avoided by a tracheotomy. Second is

34. Soung, L. S. and T. S. Ing. 1978. "Treatment of Accidental Hypothermia with Peritoneal Dialysis" (Letter), *Canad. Med. J.* 118:764 (1978).

35. Lloyd, E. L., N. A. Conliffe, H. Orgel and P. N. Walker "Accidental Hypothermia: An Apparatus for Central Rewarming as a First Aid Measure," *Scot. Med. J.* 17:83-91 (1972).

the possible inhibition of the shivering which occurs when cold air is drawn into the nose and throat.[36] It is not yet clear whether this reduction of shivering may cancel out any heat gain from the warming device. A third disadvantage is that the rate of rewarming is very slow, perhaps only slightly faster than self-rewarming. Because of the slowness of rewarming it was suggested at the Hypothermia Conference that *this method should not be considered as a rewarming method, but rather, a method of preventing further heat loss*. Testing of this procedure is still in progress.

Intragastric Balloon and Gastric Colonic Lavage:

Spontaneous or natural rewarming from the victim's body heat has long been considered the best method for treatment of chronic hypothermia. But not all experts currently agree. One condition in which it may be questionable is if the victim has cardiac arrest or ventricular fibrillation. In this case rapid rewarming is recommended by some. But even under these conditions some hearts have been reported to have started beating spontaneously during rewarming. This method can be administered wherever a warm room is available for many hours.

In conclusion, it appears that the selection of the method of rewarming is influenced greatly by personal preference, by past experiences, and by the availability of facilities to the attending physician. There is considerable debate and contradiction over the relative merits of the procedures outlined above. One of the problems in comparing the methods is that it is difficult to set up an experiment in which they could be compared. Much information about the value of a particular method is of an anecdotal nature — a physician tried a method and it worked or did not work, but he had no way to determine whether another method might have worked better or not. Any comparison is confounded by many variables. No two cases are the same in length of exposure, type of exposure, body temperature, body health and strength, body size and many other factors. Likewise, the success of a rewarming method may depend greatly on the quality of the accompanying supportive treatment.

While theory or principle might suggest the superiority of one method over another for each type of exposure, recovery has been achieved after the use of each method. Sometimes it appears that the victim has survived regardless of, or in spite of, the treatment. But this does not diminish the importance of exercising care in selecting the proper method for the situation at hand. □

36. Pozos, R. S. et. al. Presented at the International Hypothermia Conference. U. Rhode Island, 1980.